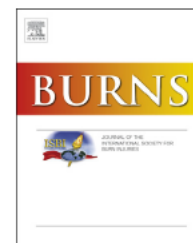


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Lack of precision of burn surface area calculation by UK Armed Forces medical personnel

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ABSTRACT

Objective: Accurate determination of the severity of burn is essential for the care of thermally injured patients. We aimed to examine the accuracy and precision of TBSA calculation performed by specialist military burn care providers and non specialist but experienced military clinicians.

Methods: Using a single case example with photographic montages and a modified Lund and Browder chart, the two cohorts of clinicians were each given 10 min to map and calculate the case example TBSA involvement. The accuracy and precision of results from the two cohorts were compared to a set standard %TBSA.

Results: The set standard %TBSA involvement was 64.5%. Mean %TBSA mapped by non specialists ($52.53 \pm 10.03\%$) differed significantly from the set standard ($p < 0.0001$). No difference was observed when comparing results from the burn care providers ($65.68 \pm 10.29\%$; $p = 0.622$). However, when comparing precision of calculation of TBSA burned, there was no evidence of a difference in heterogeneity of results between the two cohorts (F test, $p = 0.639$; Levene's test, $p = 0.448$).

Conclusions: These results indicate that experienced military burn care providers overall more accurately assess %TBSA burned than relatively inexperienced clinicians. However, results demonstrate a lack of precision in both groups.

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1. Introduction

Severe burn is a significant threat on current military operations and likely to remain so for the foreseeable future. Burn injuries continue to comprise approximately 5–10% of casualties injured during modern conflicts, including recent combat operations in Iraq and Afghanistan [1–3]. Assessment and management of burn casualties encountered on UK operations is taught according to the principles of the

Emergency Management of Severe Burns (EMSB) course (<http://www.emsb.org.uk>). The extent of the burn, expressed as a percentage of the total body surface area (TBSA) is a fundamental concept for burn care and research. First described in 1860 by Holmes [4], the idea was developed further by Berkow [5], and remains the foundation of every burn resuscitation formula in common use around the world. Several methods are described to calculate the TBSA burned. The modified Lund and Browder chart is presently advocated on deployed operations as the most accurate method [6]. In the

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potential absence of deployed personnel with specialist training and experience in the management of burned casualties, clinicians of varying backgrounds may be required to perform burn mapping and TBSA calculation using a modified Lund and Browder chart.

Considering the risks associated with TBSA cut offs for expectant management of host national casualties, and those associated with inaccurate fluid resuscitation, the aim of this study was to assess the accuracy and precision of TBSA calculation by experienced and relatively inexperienced UK military medical, nursing and allied health personnel, using a modified Lund and Browder chart.

Our null hypotheses were that (a) deploying medical personnel of all specialties can accurately map and calculate TBSA burned and (b) experienced and inexperienced clinicians are equally precise in their mapping and calculation of TBSA burned.

2. Methods

The Military Operational Surgical Training (MOST) course is run in conjunction with the Royal College of Surgeons of England. The course is the primary means by which deploying UK Armed Forces general, orthopaedic and plastic surgeons, anaesthetists, emergency physicians and nursing and allied health personnel are clinically updated for active service on operations. Two consultant burn surgeons, both members of the MOST course faculty, were provided with high quality photographic montages of a single burned casualty, encompassing all areas of the body, with additional photographic detail showing the hands, flanks, buttocks, thighs and perineum. Neither had prior knowledge of the burned casualty used in the montage. Blinded to each other's calculation, they independently mapped and calculated the TBSA burned. Based on the combination of these surgeons' civilian burn and deployed military experience, these calculations set the standard against which results were measured.

Participants on one MOST course were each provided with the same high quality photographic montages and modified Lund and Browder charts. No training in the mapping and calculation of burn surface area was given before the study. Each participant independently mapped and calculated the TBSA burned from these montages. Trade or profession and specialty were recorded. Ten minutes were permitted for the mapping and calculation. A similar study was subsequently undertaken at a meeting of the Combined Services Plastic Surgery Society (CSPSS). This meeting is attended by burns and plastic surgeons, and specialist burns and plastic surgery nurses from the three arms of the UK Defence Medical Services. The same photographic montages were provided to meeting delegates, and 10 min were permitted for mapping and calculation of TBSA burned. Lighting conditions were similar to those at the MOST course, and no training in the mapping and calculation of burn surface area was given prior to the study. Participants from this cohort were asked to provide their trade or profession and grade.

Comparison of the accuracy and precision of TBSA calculation was made between the two cohorts and between these cohorts and the set standard. Statistical analysis was

conducted by the use of two tailed, one sample and two sample *t* tests to determine differences in means. The *F* test and Levene's tests were used to examine for differences in precision of results between the two cohorts. A significance level of $p < 0.05$ was set.

3. Results

The two consultant burn surgeons independently mapped the TBSA burned to within one percent (64% and 65%). The standard was therefore set at 64.5%.

Forty results were available from the MOST cohort (16 Surgeons, 10 Anaesthetists, 2 Emergency physicians, 10 Operating department Practitioners and 2 Registered Nurses). Twenty results were available from the CSPSS cohort (5 consultant burns and plastic surgeons, 7 registrars in burns and plastic surgery, 3 senior house officers with a declared interest in burns and plastic surgery, and 4 burns and plastic surgery specialist nurses). The numbers in each subgroup were too small to permit valid subgroup analysis.

TBSA calculations from the MOST cohort ranged from 37.5% to 73.5% (mean (\pm SD) $52.53\% \pm 10.03\%$). Calculated TBSA from the CSPSS cohort ranged from 48% to 85% (mean $65.68 \pm 10.29\%$) (Fig. 1). The MOST cohort results differed significantly from the standard ($p < 0.0001$, one sample *t* test) and from the CSPSS cohort ($p < 0.0001$, two sample *t* test, difference in means 13.15%). The CSPSS cohort did not differ significantly from the standard ($p = 0.622$, one sample *t* test). Comparison of the precision of calculations did not show any evidence of a difference in heterogeneity of TBSA calculation between the MOST cohort and the CSPSS cohort ($p = 0.639$, *F* test; $p = 0.448$, Levene's test).

Null hypothesis (a) is therefore rejected. Conversely, null hypothesis (b) cannot be rejected.

4. Discussion

Severe burns present a major challenge to health care teams both in the civilian and the military setting. Accurate assessment of the TBSA burned is essential to the provision of good quality burn care. Several methods are described to calculate the TBSA burned, including the Rule of Nines [7], serial halving [8], and modified Lund and Browder charts [9,10]. The technique of serial halving and the Rule of Nines both give an approximation of the extent of the burn injury. This is thought to be adequate for assessment and triage at the pre-hospital (military Role 1 or 2) stage, but is not thought to be sufficiently accurate for planning management in a dedicated burn unit or Role 3 operational medical treatment facility (MTF). The modified Lund and Browder chart is advocated in UK clinical guidelines for operations as the best method of calculating TBSA burned [6]. When possible and appropriate, burn mapping at the UK led, multinationally staffed Role 3 MTF in Camp Bastion, Afghanistan is carried out after the first burn debridement in the operating theatre, which is located immediately adjacent to the Emergency Department. Very small burns, and those that very obviously will not survive may be mapped in the Emergency Department. Medical and

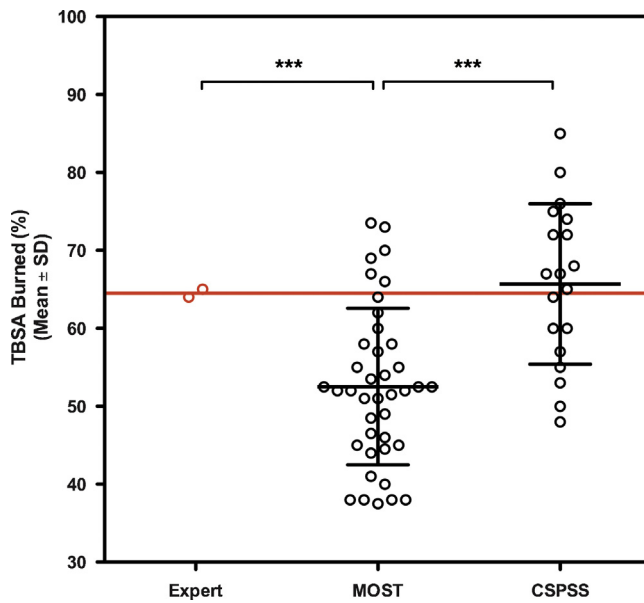


Fig. 1 – Scatter plot of results from the MOST and CSPSS cohorts, measured against the standard set by the two experts. Bars represent means and standard deviations. * $p < 0.0001$.**

nursing staffs at this facility include experienced burn care providers, but this expertise may not be maintained in future operations.

Inaccurate calculation of the percentage burn surface area is common. A number of authors have examined the differences in calculations encountered between referring emergency departments and receiving burn centres [11–14]. The majority of observed errors are attributed to a lack of accurate mapping or the use of the Rule of Nines, although Laing et al. [14], in a study of 100 consecutive referrals to a regional burn centre showed that some assessors overestimated the burn surface area by errors in excess of 100%, even when tools such as the Lund and Browder chart or the patient's palmar surface area were used.

Other sources of error exist. The palmar surface of the patient's hand is often used to approximate 1% of total body surface area [15–18]. There has been debate regarding the exact area that should be used [18–20]. The palmar surface of the hand, measured with the digits extended and adducted, from the distal wrist crease to the tips of the fingers is approximately 0.8% TBSA in an average adult male. The palm alone contributes about 60% of the hand surface area or about 0.5% TBSA. ATLS teaches that the area of the palm (hand minus digits) is equal to 1% of TBSA. Use of this doctrine, therefore, will lead to overestimation of the burn size. These inconsistencies may be exacerbated further by obesity [16,21].

It has been shown consistently that small burns tend to be overestimated and then over resuscitated by the less experienced, whereas larger burns are frequently underestimated and under resuscitated [22–24]. The large burn used in this study was underestimated by the MOST cohort, consistent with the published evidence. The majority of burns encountered in coalition casualties on combat operations are limited

to exposed hands, face and torso and their smaller size may initially therefore be overestimated [3]. Conversely, larger burns, more often encountered in host nation casualties, are often irregular and conform to a 3D surface, which makes 2D representation difficult [23].

Two previous studies have commented on inaccuracies in TBSA calculation by experienced burn care providers. Nichter et al. [25] compared 27 physicians calculations to a computer determined TBSA burned using a sketch of a single burn. These authors conclude that the mean TBSA, as calculated by their 'expert' group ($n = 6$) was at variance with the computed calculation, although less so than that from their most inexperienced group ($n = 13$). They do not comment on the heterogeneity of these results. In addition, physicians in this study were permitted to use any method to calculate the TBSA burned from the sketch. The majority used the Rule of Nines, and so the results of this study may be confounded by the method used to calculate %TBSA burned.

Smith et al. [8] used an 'expert panel' of seven burn surgeons to determine the TBSA burned of eight made up casualties when examining the utility of the Serial Halving method. They comment that the expert assessments were so wide that they had to reach a consensus value, but do not quantify the heterogeneity in these assessments.

If TBSA calculation is associated with such wide variation between observers, and the impact on treatment may be so heterogeneous, should burn care providers aspire to such highly accurate calculations? The answer is clearly yes because inaccurate burn wound surface area mapping and calculation may impact the care of the thermally injured patient during the entire hospital stay, especially in the deployed medical setting. Severity of thermal injury encountered during combat operations is used to allocate not only requirements for initial resuscitation, but also initial surgical debridement and wound care, level of en route care during evacuation of coalition casualties, and follow on surgical excision and wound closure. The initial steps of determination of severity are scrutinised at each level of care along the evacuation chain; however, incorrect triage/severity determination will inevitably lead to inappropriate resource allocation at one or more steps.

In contrast to the care of burned coalition casualties, decisions about the care of host nation casualties are made in light of the continuum of care that is available in country. UK guidelines in this regard have not been formalised, although a rule of thumb of 40% TBSA full thickness burn is presently in use. Current US clinical guidelines for deployed medical providers suggest consideration for expectant management of host nation patients with full thickness burns involving more than 50% of the TBSA [26]. Factors other than %TBSA which is full thickness should also be taken into consideration, and other models are also available to aid decision making in this context [27–29]. Each of these models and guidelines are based to a very large extent on TBSA burned, which makes accurate mapping and calculation vital.

All presently used resuscitation formulae use %TBSA burned, along with the patient's weight to predict fluid resuscitation requirements. Use of Parkland's formula (4 mL/kg/%TBSA) may lead to over resuscitation. In UK led deployed medical facilities, a 'restricted' or 'modified Parkland' formula of

2 mL/kg/%TBSA is presently used in the calculation of 24 h fluid resuscitation volumes. Use of this volume calculation results in significantly lower volumes of fluid resuscitation without apparent increase in morbidity or mortality [30]. US Armed Forces clinical practice guidelines advocate using a 'Rule of 10s' [31], which generally calculates a fluid volume somewhere between the true Parkland and Modified Brooke formulae. All formulae of course provide only an estimate of fluid requirements and resuscitation requires titration to physiologic response. Such tight titration, however, may be more difficult to achieve in the absence of specialised burn care expertise in the deployed setting, making the accurate and precise determination of TBSA burned more important.

Using the restricted Parkland formula, the MOST course mean estimate of TBSA in this study would have resulted in a 1728 mL deficit in the predicted fluid requirement of an 80 kg patient during the first 24 h. The observed difference in mean %TBSA in this example is therefore not only statistically significant, but also clinically significant. Without tight titration of fluid resuscitation to physiological response, such under resuscitation may result in hypovolemia and end organ hypoperfusion.

Over resuscitation is also potentially dangerous. Chung and colleagues have demonstrated an association between over resuscitation, development of abdominal compartment syndrome, and death. Logistic regression in this retrospective study of 58 military burn patients also demonstrated that over resuscitation was a significant independent predictor of death [30].

Most clinical and epidemiological research conducted into the management of burns use %TBSA burned as a predictor of outcome. In a majority of these studies, it is not made clear how the TBSA calculation has been reached. Heterogeneity in these calculations may influence outcomes.

We are unaware of any previous study examining the accuracy and precision of TBSA calculation by military medical staff, or of one specifically examining the precision of both mapping and calculation using images of a burned casualty. Our findings show that experienced military burn care providers, as a group, are more accurate in their assessment. This finding is consistent with the currently available evidence from civilian practice. However, we were surprised to find that results within the more experienced group were no more precise.

The limitations of this study include its small size and the use of photographic media rather than a real burn. The use of mannequins was briefly considered but a convincing representation of a burn wound is technically difficult without detracting from its complexity, which in the authors' opinion is most clearly illustrated by photographic media. The burn portrayed in this study was shown as a montage of high quality images combined with a series of close ups to clearly demonstrate difficult to see areas. The authors believe that these images provided sufficient quality to map and calculate the actual burn size. The use of a single case, rather than an assortment of examples of varying severity may reduce the external validity of this work to burns of a larger size. The assumption that the actual burn size, as calculated by the two MOST course faculty members, was accurate is probably safe given their experience and the precision of their independent calculations.

Our study suggests that the accuracy of burn mapping and calculation by a single assessor on a single occasion should not be assumed, regardless of previous training or experience.

Technology based potential solutions to this inaccuracy are in use at Role 4 (home base) burn centres [32–34]. Two dimensional computerised planimetry is employed by a number of programmes including Wound Flow [34,35], Mersey Burns [36], Burn Calculator [37] and SAGE II [38]. 3D mapping software such as EPRI 3D Burn Vision [38] strives to reduce the error inherent in representing a 3D injury in two dimensions, but requires greater training in its use. Validation of some of these solutions has been carried out by comparing mean TBSA results provided by a varying number of burn care providers [35,37,39]. These studies have demonstrated high correlations between computerised methods and manually completed Lund and Browder Charts. No studies, however, have reported the heterogeneity of the individual assessments provided using each method. Each of these solutions still requires an assessor to input the burn area by drawing it onto a computer screen or tablet, and therefore the variability in perception and representation inherent in having a human assess and draw the burn remains. Potential solutions to this source of error include 3D MRI and TeraHertz scanning technologies [40], but at the time of writing, these are not yet proven in clinical practice, and are unlikely to be deployed in combat operations in the foreseeable future.

A pragmatic potential solution to this problem, and one that is likely to have greater applicability in deployed practice, is for at least two experienced burn care providers, medical or nursing, to map and calculate the TBSA burned. Comparing at least two calculations at each time point should ensure greater precision by allowing for inter observer discussion to rationalise the result. This method is currently being evaluated at the Role 3 MTF at Camp Bastion. Although it has not yet been proven to improve outcomes, it is conjectured that this may lead to a more accurate and precise determination of burn wound severity.

Conflict of interest

N.A.J.M. and R.F.R. are employed by the British Army and the Royal Navy, respectively. J.B.L. is employed by the US Army. The opinions expressed in this article are those of the authors and not of the UK Ministry of Defence or the US Department of Defense.

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